Network Dilation Anomaly in Ion-Exchanged Glasses Quenched under Pressure

Wang, Mengyi; Smedskjær, Morten Mattrup; Mauro, John C.; Sant, Gaurav; Bauchy, Mathieu

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M. Wang[1]; M. M. Smedskjaer[2]; J. C. Mauro[3]; G. Sant[*1]; M. Bauchy[1]

1. University of California, Los Angeles, USA 2. Aalborg University, Denmark 3. Pennsylvania State University, USA

Ion exchange is commonly used to strengthen oxide glasses. However, the resulting stuffed glasses usually do not reach the molar volume of as-melted glasses of similar composition—a phenomenon known as the network dilation anomaly. This behavior seriously limits the potential for the chemical strengthening of glasses and its origin remains one of the mysteries of glass science. Here, based on molecular dynamics simulations, we investigate the effect of pressure-quenching on the network dilation anomaly in a sodium silicate glass. We show that the application of pressure during quenching results in permanently densified glasses that exhibit varying network topology/rigidity. In turn, the topology of the atomic network is found to control the extent of ion exchange-induced dilation. In particular, we demonstrate that optimally constrained (isostatic) glasses do not show any network dilation anomaly. This is found to arise from the combined absence of floppy modes of deformation and internal eigenstress in isostatic atomic networks. This demonstrates that finely tuning the rigidity of glass networks can enhance the effect of ion-exchange and, thereby, could lead to the design of stronger glasses.